Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/AU04/001693

International filing date: 03 December 2004 (03.12.2004)

Document type: Certified copy of priority document

Document details: Country/Office: AU
Number: 2003906722
Filing date: 04 December 2003 (04.12.2003)

Date of receipt at the International Bureau: 04 January 2005 (04.01.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

PCT/AU2004/001693

Australian Government

Patent Office
Canberra

I, JANENE PEISKER, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003906722 for a patent by BISHOP INNOVATION LIMITED as filed on 04 December 2003.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

WITNESS my hand this
Seventeenth day of December 2004

JANENE PEISKER
TEAM LEADER EXAMINATION
SUPPORT AND SALES

RACK FORGING APPARATUS

TECHNICAL FIELD

The present invention relates to a die for forging of an automotive steering rack and in particular to a die for flashless forging of an automotive steering rack.

BACKGROUND

Automotive steering racks are known to be produced by either a machining or a forging process. On a mass manufacturing basis, machining processes are limited to manufacturing racks with constant pitch teeth only. Forging however can equally and readily produce racks with either constant or variable pitch teeth.

Most rack forging processes in use today create substantial flash when using uniform diameter solid bar stock material. This is due to the cross-sectional area of the toothed portion being smaller than that of the shank portion, which necessarily results in the excess material being expelled in between the main die members during the forging stroke.

In a basic die apparatus such as that depicted in Figures 3 to 5 of JP 58218339 (Isogawa et al), the excess material simply escapes out in the open. This die apparatus provides no means for controlling the cavity pressure. Also the resulting tooth fill may be poor and the amount of flash so created can be substantial depending on the motion of the die members and the initial blank size being used.

GB 2088256 (Jidosha Kiki Co Ltd) and GB 2108026 (Cam Gears Ltd) disclose attempts directed towards maintaining higher cavity pressures and assisting tooth fill throughout the forging stroke by incorporating flash gutters of various designs into the die members. However, material may still escape into these flash gutters prematurely, thereby limiting the admitted hydrostatic pressure which may cause under filling of the die cavity. A much more sophisticated design is presented in US 5,992,205 (Bishop), which aims at maintaining adequate hydrostatic pressure and thereby assist in achieving an adequate tooth fill.

Apart from flash being a waste of material it also needs to be removed post forging, which adds to the costs of manufacture of the rack. Even further costs may arise if a cold coining operation is required post forging to establish final tooth accuracy, such as disclosed in GB 2088256.

The die apparatus and methods disclosed in US 4,116,085, US 4,7515,210, US 4,571,982 (all in the name of Bishop et al), eliminate the need for cold coining and suppress the formation of flash all together, thereby enabling an environmentally friendly high precision forging process. Further to these advantages, the methods disclosed therein also allow the imparting of a general cross sectional shape of the toothed portion of the rack. The racks forged by these die apparatuses have a generally Y-form cross sectional shape and are often referred to as Y-racks. These are distinguished from the conventional cross sectional shape of racks, which are substantially D-shaped.

Dies for flashless forging of solid D-racks and their toothed portions have been disclosed in JP 58013431 (Jidosha Kiki Co Ltd) and JP 03138042 (IS Seiki KK et al). In these cases the enclosing diameter of the forged tooth portions exceeds that of the bar stock nominal diameter as the volume of the toothed portion of the rack must, for flashless forging, remain equal to the volume of the parent cylindrical portion. Such racks provide no product advantages over Y-racks. Although claimed to be forged without flash, process shortcomings are still associated with racks so produced as they can not be centreless ground over their entire length, as is currently done for machined D-racks. Also, complications often arise during assembly because the seals have to be assembled from the same side end.

It is therefore an object of the present invention to provide a die apparatus for flashless forging of steering racks that ameliorates at least some of the problems of the prior art.

SUMMARY OF INVENTION

According to a first aspect the present invention consists in a die for flashless forging of a steering rack having teeth from a blank, said die comprising at least two die members and at least one punch member, at least one of said

die members and said one punch member relatively moveable to converge on said blank when placed in said die, said die members having forming portions substantially the obverse form of said steering rack, said die members defining between them a cavity when said die members converge to a closed position to at least partly forge said steering rack, **characterised in that** said punch member is adapted to perform an inward movement and thereby urge said partly forged blank to substantially fill said cavity.

Preferably said rack is finish forged after said punch has completed said inward movement.

Preferably said punch member enters said cavity via a peripheral aperture located in at least one of said die members.

Preferably said aperture is formed when said die members converge to said closed position to at least partly forge said steering rack.

Preferably said forged rack has a D-shaped cross section.

Preferably said aperture is located radially and or axially.

Preferably said cavity is substantially closed after said punch member is inserted into said aperture.

Preferably said blank is a solid bar.

Preferably said blank is a hollow bar and said die further comprises a mandrel member adapted to be inserted into the bore of said hollow bar prior to said forging.

Preferably said forged rack has teeth with variable pitch.

Preferably said forged rack has teeth with constant pitch.

Preferably said at least two die members comprise one stationary die member and one moveable die member.

DESCRIPTION OF DRAWINGS

In order that the invention may be readily understood and put into practical effect, reference will now be made to the accompanying drawings, in which:-

Fig. 1 is a perspective view of a die in accordance with a first embodiment of

the present invention,

Fig. 2 is a perspective view of the die shown in Fig. 1 partly sectioned along plane 22.

Figs 3a-d are front views of the die shown in Fig. 1 sectioned along plane 24.

Fig. 4 is a perspective view of a die in accordance with a second embodiment of the present invention,

Fig. 5 is a perspective view of the die shown in Fig. 4 partly sectioned along plane 62.

Figs 6a-d are front views of the die shown in Fig. 4 sectioned along plane 64.

Fig. 7 is a perspective view of a steering rack forged using the die shown in Fig. 4.

Fig. 8 is a sectional perspective view of a die in accordance with a third embodiment of the present invention,

Fig. 9 is a perspective view of a variable tooth pitch steering rack forged using the die shown in fig. 1 or fig. 5, and

Fig. 10 is a partly sectioned perspective view of a die in accordance with a fourth embodiment of the present invention.

BEST MODE OF CARRYING OUT THE INVENTION

Figures 1 and 2 depict die 10 according to a first embodiment of the present invention. Die 10 comprises a first die member 14, a second die member 16 and a punch member 18. Rack 12 is forged utilising die 10 in combination with a suitable forge press, such as described in US 3,802,248 (Ross et al). Forging is achieved by the relative movement of the first die member 14 upon the second die member 16.

Rack 12 comprises shaft portion 25 and tooth portion 26, which may be of the type which has gear teeth of constant pitch or of the type that has gear teeth with a varying pitch.

When first die member 14 abuts second member 16, a cavity 13 is formed which has an aperture 11 located at its periphery (see also figs 3a to 3d). Aperture 11 allows punch member 18 to access to rack 12. Cavity 13 is shaped such that its form is substantially the obverse of the rack portion to be

forged, and such that when the first and second die members 14, 16 make contact, rack 12 is partly forged.

Cavity 13 is also shaped such that the circumscribing diameter of the toothed portion 26 is located fully within the diametrical constraints and is coaxial with the shaft portion 25. In order to achieve a flashless forging from a solid blank, the blank diameter in the toothed portion 26, and in the portion between the toothed portion 26 and the shaft portion 25, must be less than that of the shaft portion 25.

In this embodiment, punch member 18 begins to move into cavity 13 when first and second die members 14, 16 have completed there relative motion. Alternatively, punch member 18 may begin its movement simultaneously with that of second die members 14, 16. The action of punch member 18 completes the forging process by applying enough forging load such that rack 12 substantially fills cavity 13. In this way, rack 12 may be finished forged without formation of flash, which would otherwise require removal by the addition of a trimming or a machining process. Movement of punch member 18 may be effected by a linkage arrangement connected to the ram of the aforementioned forge press, or alternatively some alternate actuation means may be utilised.

The process of flashless forging is further explained by examining figures 3a to d. Figures 3a to d are sectional views of the die 10 cut along section plane 24 (figure 1) and depict the above mentioned process at various stages of die forging. Figure 3a shows first die member 14 above second die member 16. Blank 12a is in the form of a round bar and as yet had no forging load applied to it. At this point in the process, punch member 18 is located within aperture 11 but has not yet applied any forging load onto blank 12a. First die member 14 includes a tooth forming portion 28 which also has not yet applied any forging load.

Figure 3b shows a subsequent stage of the forging stroke according to the first embodiment, wherein the forging load has begun to be applied upon blank 12a. As can be seen from this figure, tooth forming portion 28 has been substantially impressed into blank 12a due to the first die member 14

approaching second die member 16. Rack pad contact portion 19 of blank 12a has also substantially formed. Second die member 16 is stationary and all forging load applied is due to the movement of first die member 14. Punch member 18 does not move relatively through die member 16 until first die member 14 has contacted second die member 16.

Figure 3c shows a further stage in the forging stroke according to the first embodiment wherein blank 12a has now transformed into partly forged rack 12. First die member 14 now abuts second die member 16 such that both die members 14, 16 do not move relatively thereafter. It can be seen from this figure that a radially sealed cavity 13 has been formed by the closed contact of the first and second die members 14, 16. Cavity 13 now substantially forms the obverse form of rack 12 and is designed such that unfilled areas 30 are formed. Once relative movement of the first and second die members 14, 16 is complete punch member 18 begins to move upwardly towards first die member 14. Despite rack 12 being substantially formed, unfilled areas 30 are an important feature of the present embodiment, in that, they ensure that the forging of rack 12 does not force excess material between the members 14, 16 and 18.

Figure 3d shows the final stage of the forging stroke according to the first embodiment. Punch member 18 has now completed its upward movement, thereby exerting the final forging load onto rack 12 and imparting the final die cavity hydrostatic pressure. As a result, unfilled areas 30 of figure 3c are substantially filled without material escaping in between any of the members 14, 16 and 18. A further feature of the present embodiment is that the travel of punch member 18 is designed to control the degree of filling of the rack teeth and cavity 13 during forging. Rack 12 is finished forged without any flash occurring and within the diametrical limits of the shaft portion 25 as well as the toothed portion 26 being formed coaxial with the shaft portion 25. This enables a considerable cost saving in the manufacture of steering racks because, apart from saving material, it eliminates the need for flash removal post forging.

It should be understood that the aforementioned process is not limited to the steps depicted by 3a-d, that is, variations may be required to suit different rack

configurations. Also, the described motion of the die members may be reversed if die 10 is inverted.

Figures 4 and 5 depict die 50 according to a second embodiment of the present invention. Die 50 comprises a first die member 54, a second die member 56 and punch members 58. Similar to the first embodiment, die 50 is used in conjunction with a suitable forge press to forge rack 52.

Unlike the first embodiment, two punch members 58 are used instead of only one as in die 10. During the forging process, punch members 58 act radially upon rack 52, this results in punch contact area 72. Having two punch members 58 exerting forging load rather than only one is advantageous because it enhances the controllability of the forge process and is better suited to rack pad designs where a central longitudinal groove in the rack pad is deemed to be undesirable.

Figures 6a to d depict the forging process of the second embodiment in a similar way to figures 3a to d of the first embodiment. It should be understood that the travel of punch members 58 is controlled such that the rack adequately fills the cavity 53 with no material escaping in between die members 54, 56 and punch members 58. The description of each of the sequential stages depicted in figs 6a to d is similar to those depicted in figures 3a to d of the first embodiment and will not be repeated.

Figure 7 depicts rack 52 which is the exact obverse of the form of cavity 53 when die members 54, 56 and punch members 58 are in their final position. Punch contact area 72, rack teeth 66 and rack shaft 74 are clearly shown. As with rack 12, rack 52 is of the type known as having a "D" cross section, or alternatively known as a "D rack". As mentioned earlier, racks produced by the dies of the present invention are finished forged and do not require any finish machining of the teeth or flash removal after forging.

Figure 8 depicts die 100 according to a third embodiment of the present invention. Unlike the racks produced in the first and second embodiments, rack 112 is not a full length rack and will need to be joined to a shaft portion before it is installed into a vehicle steering gear. One method of joining rack

toothed portions to shaft portions is described in JP 06207623 (Sekiguchi Sangyo KK).

Die 100 differs from the dies of the previous embodiments in that it includes an axial punch member 108 and mandrel member 110. Axial punch member 108 provides extra control over the forging process as well as a means to control rack 112 final length.

Axial punch 108 is used in combination with radial punch members 106 (only one shown) in the same way to the way that punch members 18, 58 are used in the first and second embodiments, differing only because of the addition of mandrel member 110, which is required for a hollow rack. Mandrel member 110 is inserted into the bore 113 of rack 112 before any forging load is applied, that is, before any relative movement of the die members 102, 104 occurs. Mandrel member 110 is removed after the forging process is complete to leave a hollow rack 112. Hollow racks are desirable in vehicle steering gears because of their light weight and reduced material consumption.

An alternate rack shape configuration that can be forged by any of the above mentioned embodiments is depicted in figure 9. Figure 9 depicts rack 140, which differs from the racks mentioned above in that, rack 140 has gear teeth with a varying cross section, skew angle and tooth pitch. That is, tooth portion 144 has a cross section, skew angle and tooth pitch that is different to tooth portion 146. This type of rack configuration cannot be sensibly machined in mass manufacture and is therefore very appropriate to the forging die of the present invention. The merits of variable pitch steering racks are well known and will not be expanded on here, suffice it to say, that the aforementioned dies of the present invention have the ability to forge gear teeth of any tooth configuration without flash.

Figure 10 depicts die 150 according to a fourth embodiment of the present invention. Die 150 comprises first die member 152, second die member 154, first axial punch member 156 and second axial die member 158. Rack 160, like rack 112, is a short rack that will be required to be axially extended before installation in the finished steering gear. In this embodiment, the radial punch

members of the previous embodiments have been replaced by two axial punch members 156, 158.

The operation of die 150 is similar to previous embodiments, wherein first die member 152 moves relative to second die member 154 and axial punch members 156, 158 either move simultaneously with die members 152, 154 or start moving after die members have contacted each other. Upon the completion of the movements of die members 152, 154 and axial punch members 156, 158, rack 160 is finished forged.

Shortened rack 160 may be forged using die 10 of the first embodiment or die 50 of the second embodiment. For example, die 50 may or may not incorporate axial punch members 156, 158 as shown on figure 10. Furthermore, it may be decided to split die members 152, 154 at either end of cavity 113 to incorporate loading and unloading gripping devices. Also, it will be appreciated that this embodiment may operate when the punch members of either embodiment 1 or 2 are added, without departing from the scope of the invention.

It should be understood that the forged racks depicted in figures 1-10 are shown with their features i.e., the teeth and punch member mating faces, as solid lines, hence suggesting that the die cavity would be entirely filled. In practice this degree of fill would neither be achievable nor desirable in a mass production. That is, a commercially forged rack would desirably show some degree of underfill, being apparent by rounded features.

It should also be understood that for reasons of clarity, various supports, journals, bearings and control units have been omitted from the figures.

Although the present invention has been herein shown and described in four embodiments, it is recognised that departures from, and combinations of these embodiments may be made without departing from the scope of the invention. Also, the present invention is primary intended to be used to forge steering racks made from steel but may alternatively be used with other forgeable materials.

It will also be appreciated that simultaneous motion of the die and punch members, in any of the aforementioned embodiments, is only acceptable if the

movement of the punch member(s) is completed after the die members have completed their relative motion. This is simply achieved by either having a (not shown) speed or displacement differential mechanism between the die and punch members.

The term “comprising” as used herein is used in the inclusive sense of “including” or “having” and not in the exclusive sense of “consisting only of”.

The term “flash” as used herein refers to the excess material that extends out from the body of the forging to ensure complete filling of the die cavity. It is a common feature of an open die process. The flash formed in open die forging is substantial and must be removed by a trimming, machining or grinding process. The term “flashless forging” as used herein refers to closed die forging in which virtually no excess material is allowed to escape from the die cavity.

It should be understood that the term “forging” may refer to hot, warm or cold forging.

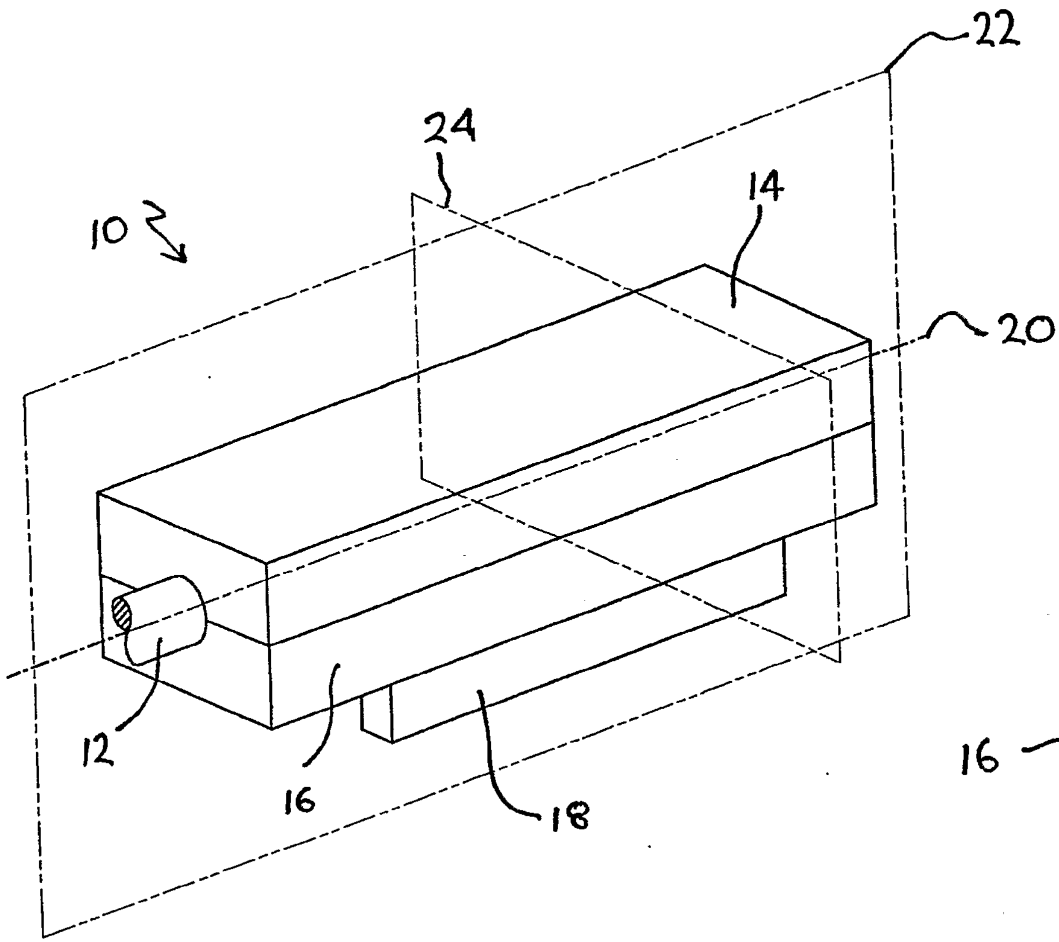

Fig 1.

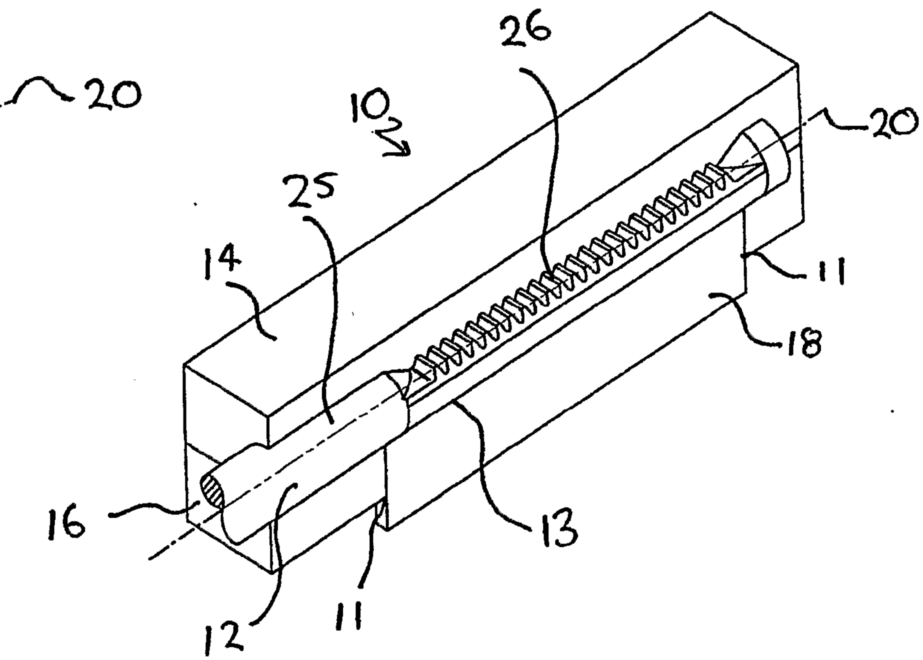

Fig 2.

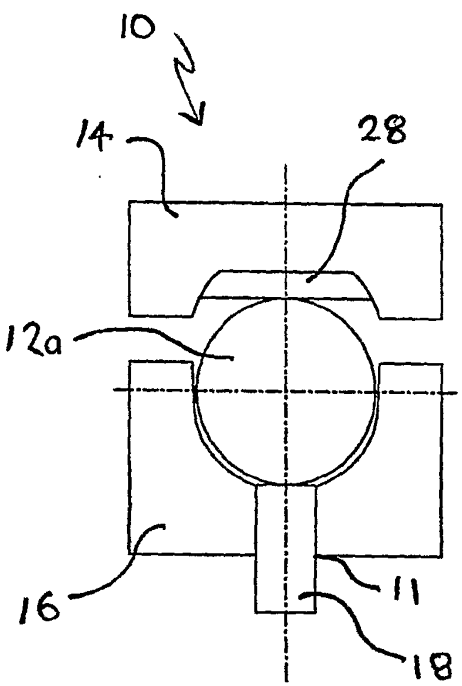

Fig 3a.

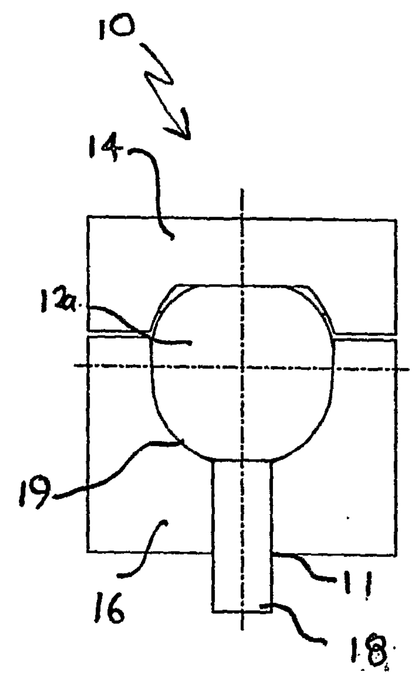

Fig 3b.

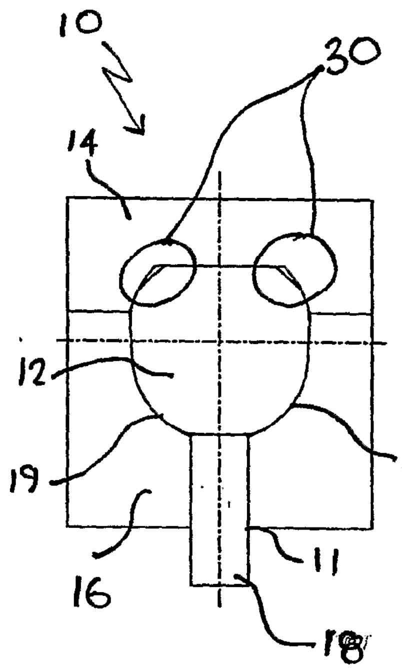

Fig 3c.

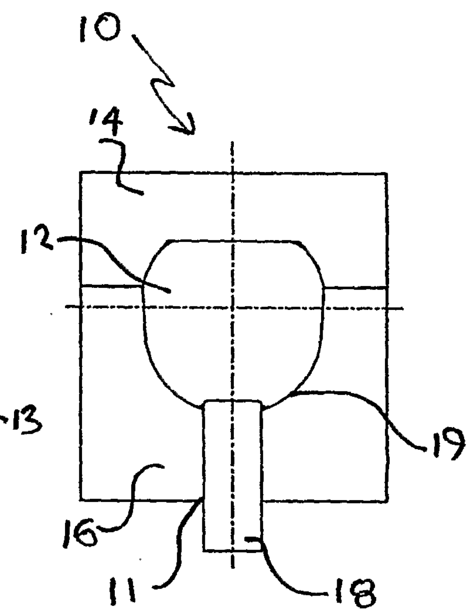

Fig 3d

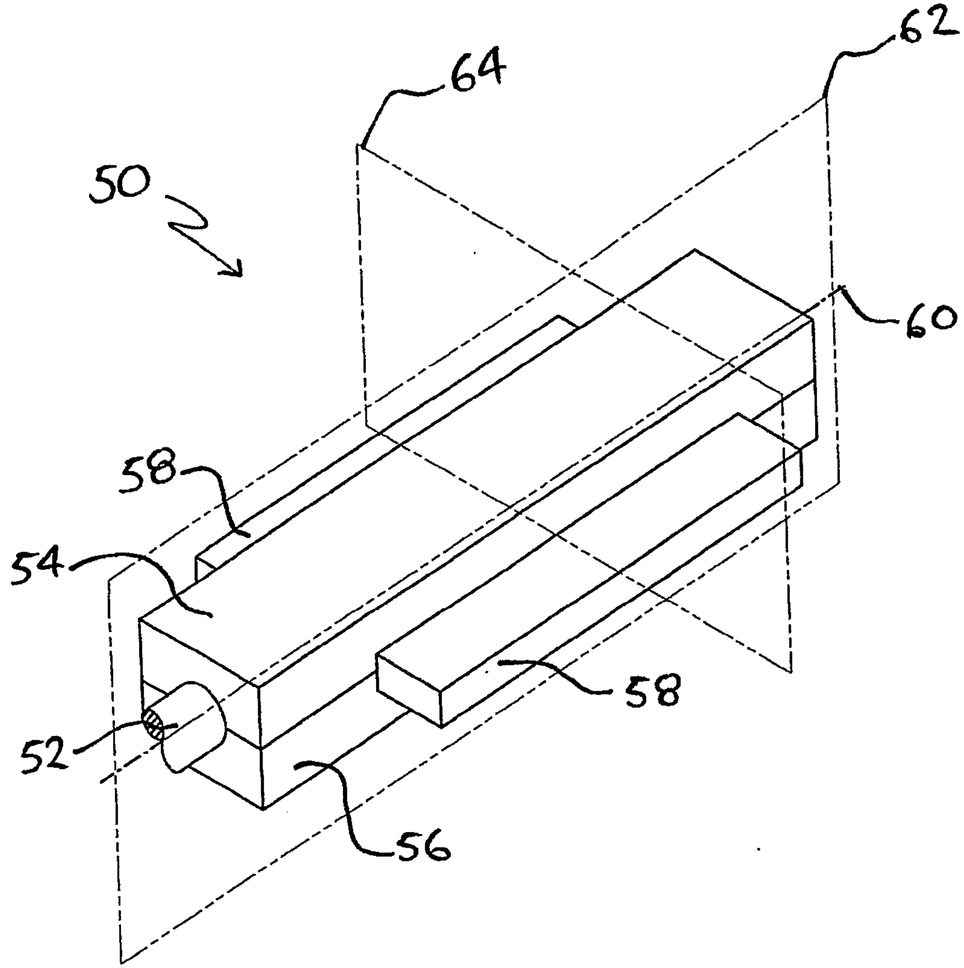

Fig 4.

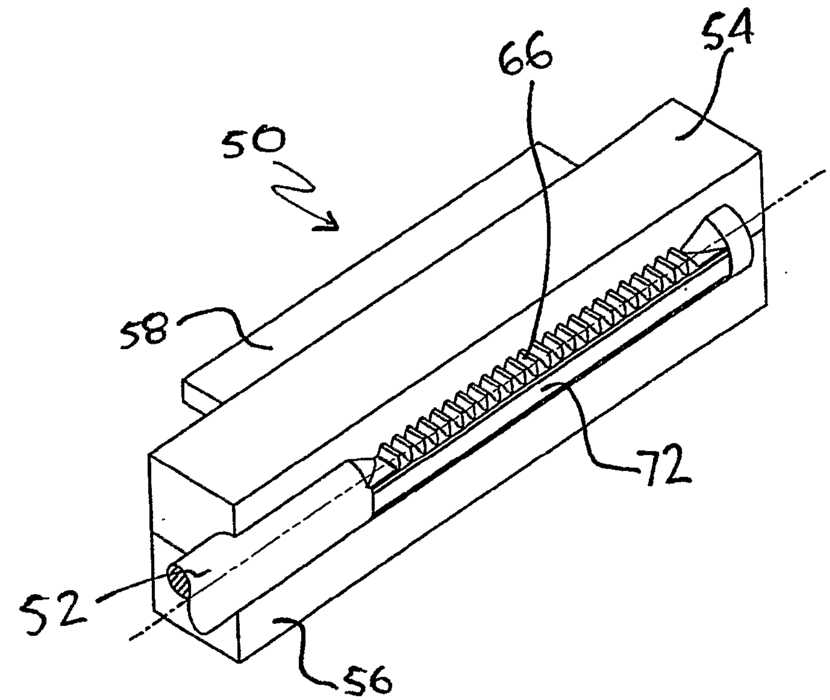

Fig 5.

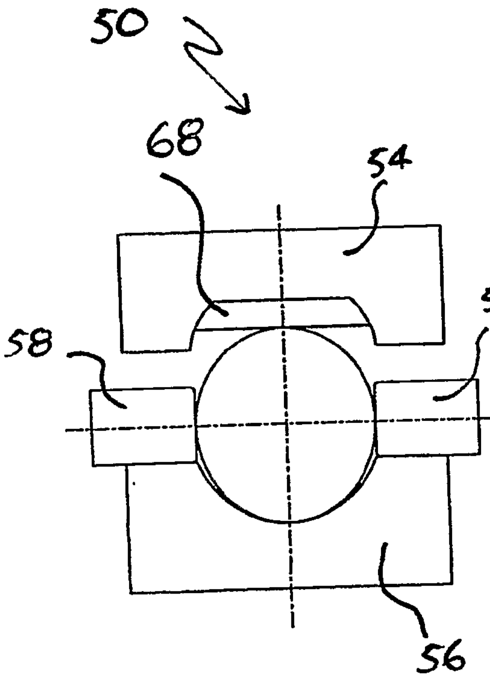

Fig 6a.

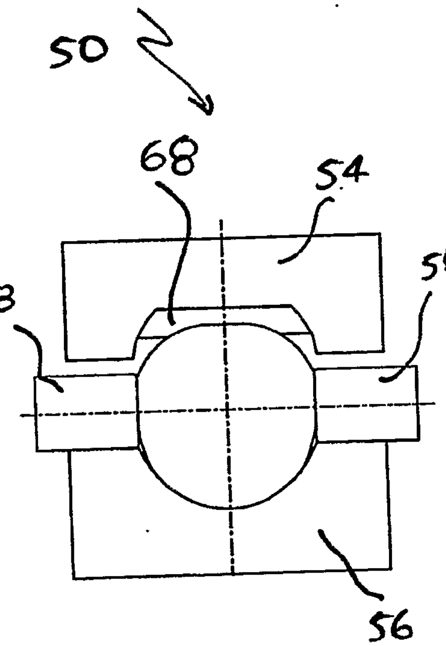

Fig 6b.

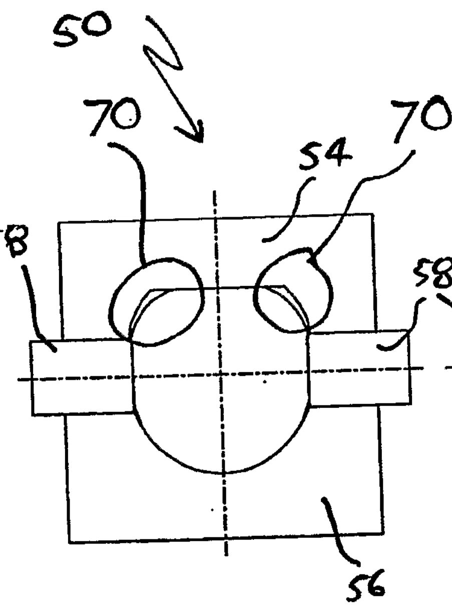

Fig 6c.

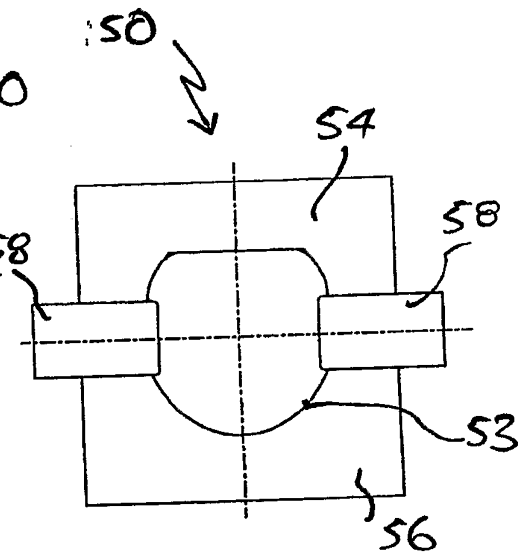

Fig 6d.

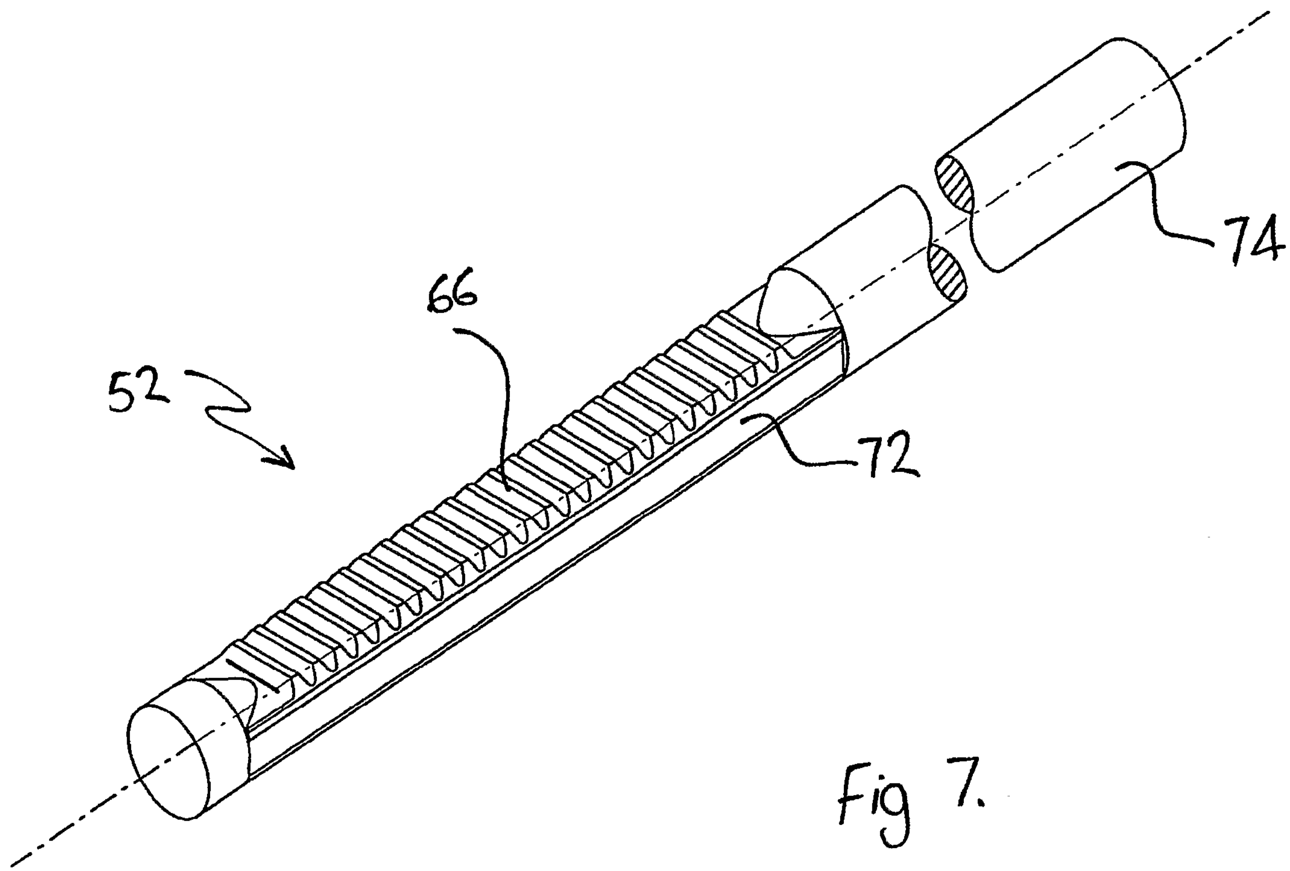

Fig 7.

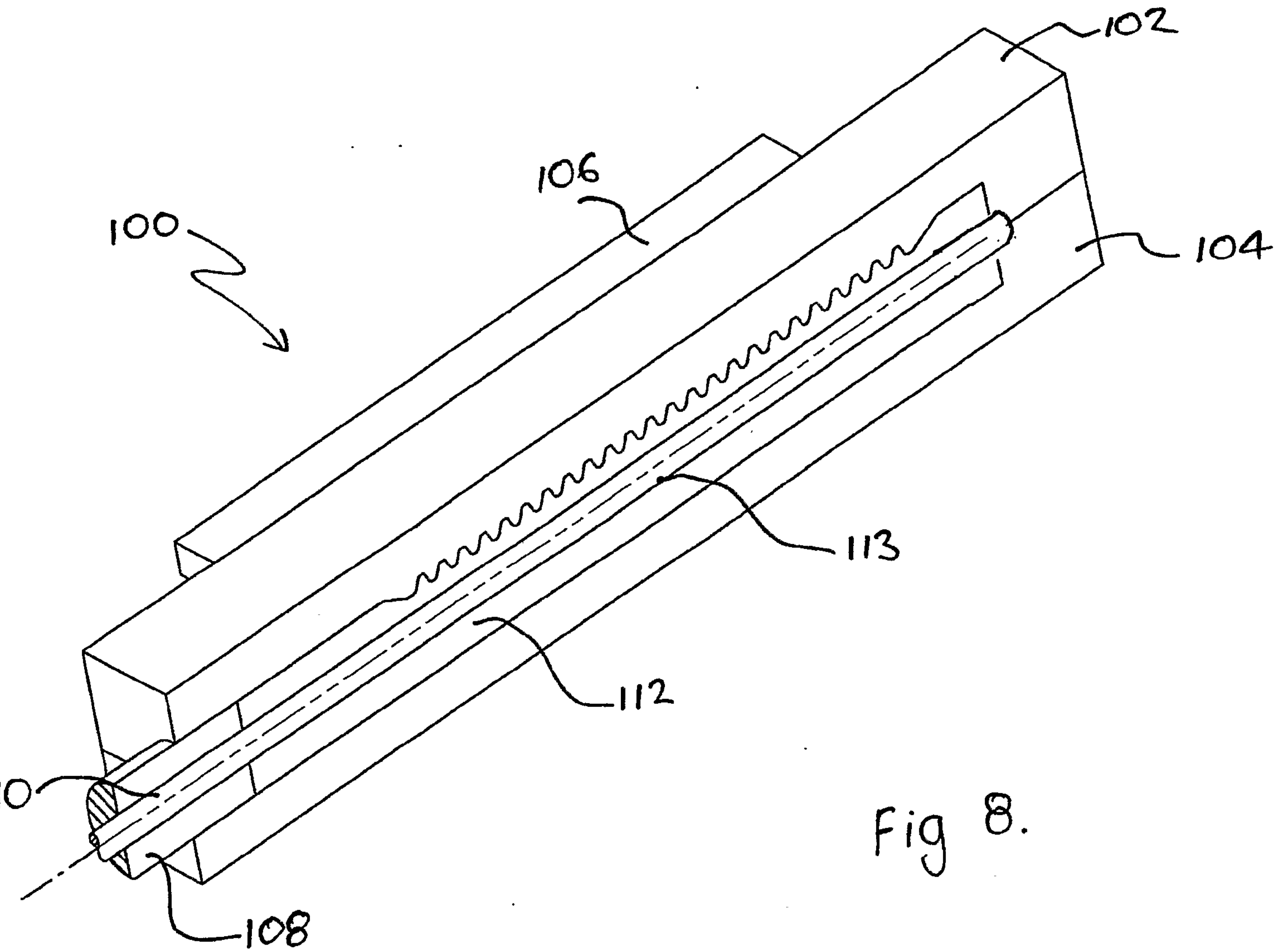

Fig 8.

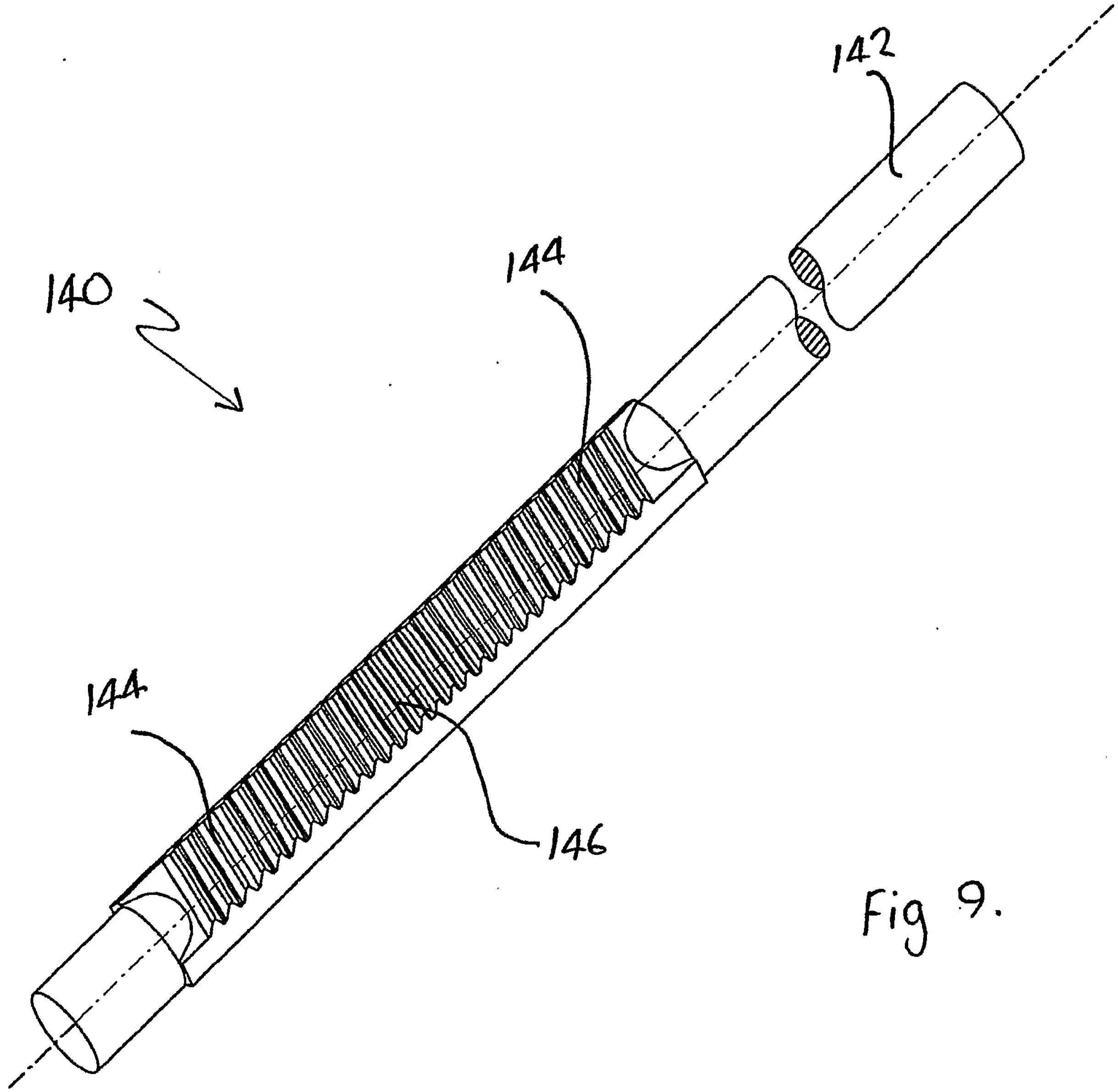

Fig 9.

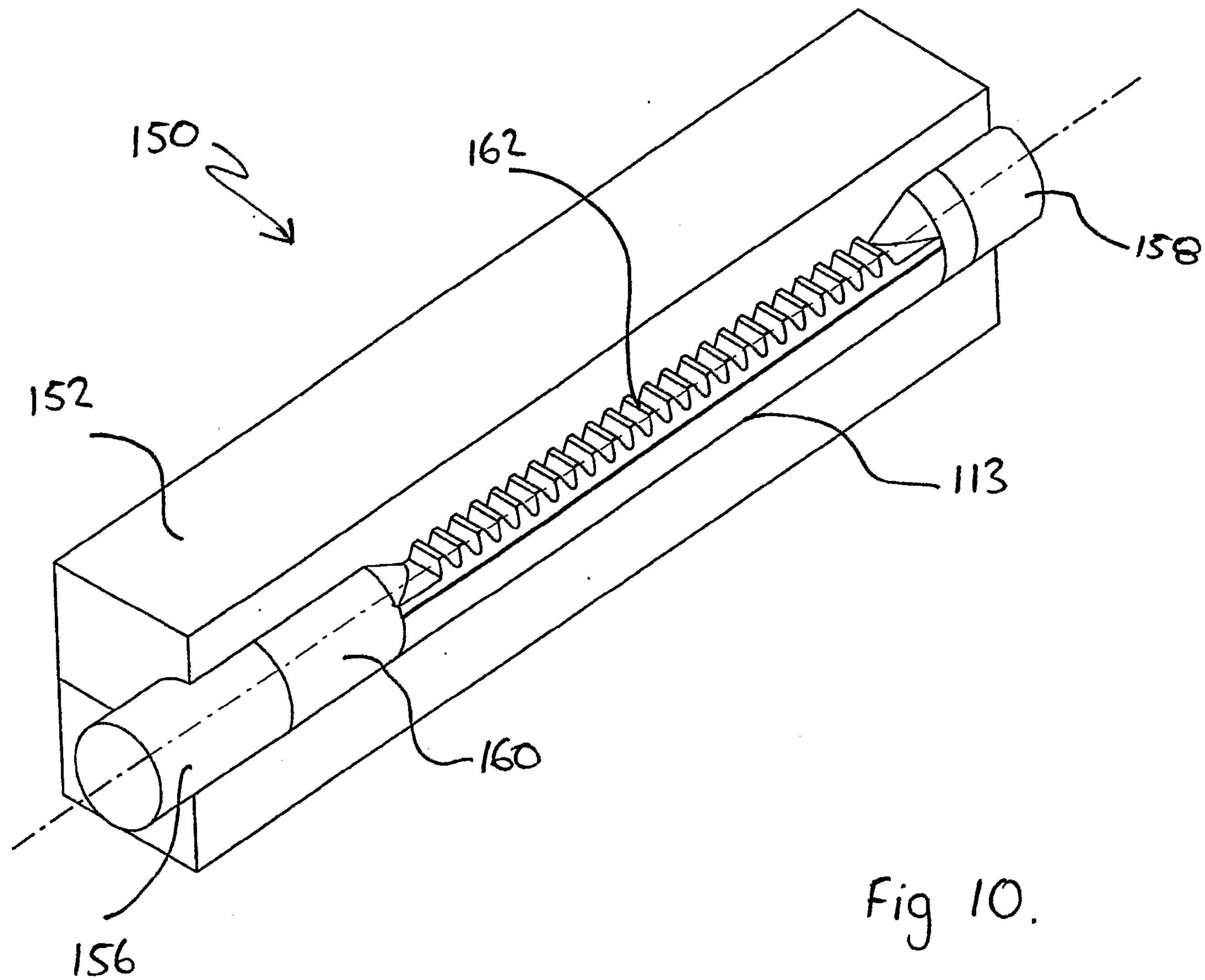

Fig 10.